which their existence is known. The throw of these minor faults varies from a few feet to several hundred. The faults enumerated are more frequent in the trap than in the shale and sandstone. Since faults are much more easily detected where they affect the trap, owing to the fact that this formation has come to assume the form of ridges since the faulting, it is inferred that minor faults affecting the more homogeneous portions of the sedimentary part of the system may have escaped observation.

But for the faults, the determination of the thickness of the system would be an easy matter. Allowance can be made for the faults which are known, but there is no way of taking quantitative account of those which have not been discovered. Impressed with the fact that there may be many undiscovered faults of slight extent in the homogeneous shales and sandstones, Dr. Kümmel has revised his estimate of the thickness of the system, and now gives the following figures:

Brunswick series, - - - - -	6,000 to 8,000
Lockatong series, - - - - -	3,500 to 3,600
Stockton series, - - - - -	2,300 to 3,100
	11,800 to 14,700

The thicknesses of the principal sheets of trap are also given, the thickest being less than one thousand feet. A brief discussion of the conditions of the origin of the system is followed by a résumé of its economic resources.

The report, as a whole, presents in excellent form the results of a piece of work which is not likely to need revision. It is a matter of congratulation that Dr. Kümmel has this year been able to extend his studies over the Triassic area of New York.

R. D. S.

The Geological History of the Isthmus of Panama and Portions of Costa Rica. By ROBERT T. HILL, Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XXVIII, No. 5, pp. 151–285. Nineteen plates. Cambridge, 1898.

The results embodied in this report are based on a reconnaissance made by the author for Alexander Agassiz in 1895. In spite of the fact that the region concerned was only reconnoitered, the report adds

much to our knowledge of tropical America. Some of the geographic features which characterize the region have been briefly described by the author in earlier publications, but the geological results of the reconnaissance have not before been published. So far as practicable, Mr. Hill's conclusions are stated in his own words.

In the first place, emphasis is laid upon the independence of the North American, Central American, and South American orogenic systems. The Cordilleran system of North America ends in Mexico, a little south of its capital city. The Andean system of South America has its northern terminus east of the Isthmus of Panama, and has no genetic connection with the mountain ranges of the north coast of South America. If the Cordilleran and Andean systems were extended southward and northward respectively, they would pass each other in parallel lines hundreds of miles apart. The extension of the Andean system would lie not only east of the Cordilleran, but even east of the Appalachians, while the extension of the Cordilleran system would lie in the Pacific, far west of the South American coast.

Between the termini of these orogenic systems, with a trend at right angles to both, lies a third system, called the Antillean. It is this system of mountains which has determined the major topographic features of the Antillean region. The system includes the east-west ranges of the north coast of South America, those of the Isthmus, Central America, southern Mexico, and the Great Antilles. In the Caribbean sea, two east-west submarine ridges, separated by the Bartlett Deep, show that the east-west trend of the crustal corrugations of this region affect the sea bottom as well as the land. Like the greater systems to the north and south, the Antillean system is composed of folded sedimentary rocks, plus volcanic intrusions and ejecta. While each of the major orogenic systems dominates a continental area, the Antillean system "constitutes a mountainous perimeter surrounding the depressed basin of the Caribbean."

The primary geographic features of that part of the continent dominated by the east-west system are 1°, a volcanic plateau near the Pacific coast along the western termini of the ranges of the Antillean system, and 2°, the lower but mountainous area facing the Caribbean, consisting of folded beds of sedimentary rock, associated with igneous. To the north, the western termini of the Antillean ranges are buried by the volcanic rocks, but on the Pacific side of Panama, the Antillean ranges continue across the land area.

The surface of Panama is described as consisting of irregularly rounded mountains and hills, 200 to 1500 feet in height. Their topographic expression is uniform whatever the rock of which they are composed. Lack of systematic arrangement in their distribution is said to be one of their striking features, though an east-west trend is locally observable. Their form and arrangement are ascribed primarily to erosion.

"In common with the whole Central American region south of Yucatan, the Isthmus of Panama presents no such feature as a well-defined coastal plain like that bordering the eastern and southern margin of the United States. . . . . Such occasional levels as may be recognized on either coast are the products of the erosion of the greatly distorted sedimentaries and volcanic rocks. . . . . The Caribbean coast is generally marked by jagged and abrupt bluffs where the sea beats directly against the hills. The indentations are slight and far apart. The same may be said of the Pacific side."

The drainage of the Isthmus is defined as "ancient, mature and autogenous, consisting of deeply incised headwater ramifications drowned in their lower courses toward the sea." Although the drainage of the Isthmus is about equally divided between the two oceans, there is no well defined watershed separating the waters flowing into the Atlantic from those flowing into the Pacific.

The Isthmian region is now undergoing rapid erosion, the result of the excessive rainfall (154 inches in 1894), and of the activity of the waves of the oceans. The topography of the sea bottom on either side points to a former greater expansion of land, and therefore to the fact that the narrow neck of land is, and has been disappearing under the influence of the agencies mentioned. This conclusion is further borne out by the outlying islands, which, by their structure and relations, show themselves to be isolated remnants of the mainland.

Two detailed geological sections are given, one across the Isthmus from Colon to Panama, and the other across Costa Rica. In the Isthmian section, seven structural units are recognized. These are (1) the fringing coral reefs; (2) the coastal swamps of both coasts—elevated plains of sedimentation; (3) the Monkey Hill and Panama benches—elevated base-leveled plains; (4) the folded and disturbed Tertiaries which owe their positions to the series of post-Tertiary (post-Oligocene) orogenic foldings along the Caribbean side of a more ancient nucleal region; (5) the numerous protrusions of basic igneous rocks,

the age of which is not definitely known; (6) the sedimentary rhyolitic and andesitic tuffs, the Panama formation, older than the basic igneous formations; and (7) the granitic rocks, the oldest of the region. The sedimentary rocks of the section fall into three categories: (1) those of supposedly pre-Eocene age, occurring on both sides of the Isthmus; (2) the fossiliferous Tertiary beds of the Caribbean side, and (3) the Pleistocene beds deposited synchronously on both sides.

The rocks of the first of these three classes are so distorted and concealed by later igneous protrusions and deposits that little was learned of their relations. They are composed almost entirely of rhyolitic and andesitic material. The beds of the second class are referable, on the basis of their fossils, to the Eocene and Oligocene, corresponding approximately with the Tejon, Claiborne and Vicksburg formations of the United States. They are composed mainly of muddy sediments with more or less sand, glauconite and lignite. Limestone occurs at two horizons. It is to be specially noted that the Tertiary deposits of the Isthmian section end with the Oligocene (early Miocene), and there is nothing to indicate that sedimentation was in progress in the Isthmian region during the later Miocene and Pliocene epochs. The inference is that "the Isthmian land was of much larger area during these later epochs than in Eocene time or at present." The thickness of the Tertiary system is thought to be as much as 1000 feet, and possibly much more.

The igneous rocks of the Isthmian section consist of (1) granite in ranges having an east-west trend; (2) rhyolitic tuffs and pumice, igneous in origin, but sedimentary in arrangement; and (3) basic igneous rocks, occurring as intrusives, eruptives, tuffs, etc. The basic rocks are younger than the others, but are thought to have been in existence during the deposition of the later Eocene sediments. Other considerations prevent the reference of these rocks to an earlier period, and lead to the conclusion "that the most marked volcanic episode of the Isthmian region took place during the later Eocene epoch." It is thought that there are also late Tertiary syenitic intrusives, which "now form the core of great mountainous protuberances."

Throughout the Isthmian region, the surface red clays conceal all the formations. They are believed to be largely the residuum of rock decay. The extent of this decay is said to be "enormous, extending often to a depth of over 100, and seldom less than fifty feet."

In the Costa Rican sections the principal geological features may

likewise be grouped in seven categories. There are (1) the foundation rocks of ancient quartzites, serpentines, jadeite, and granite, probably pre-Cretaceous; (2) limestones, which are believed to be Cretaceous; (3) basic igneous rocks of Eocene, and possibly of late Miocene age; these rocks conceal most of the older formations and are, in turn, largely buried beneath later volcanics; (4) the marine Tertiary sediments, Eocene to Pliocene inclusive, of the Caribbean side; the early beds of this group are extensively disturbed, elevated and broken through by igneous protrusions; against these deformed and eroded strata the Pliocene beds rest unconformably; (5) a line of volcanoes surmounting the Sierras; (6) the Pleistocene sediments of the coasts, and (7) the "bolsons," base-leveled plains, benches, canyons and other topographic features.

In this section the "bowlder clays" of tropical America are encountered. The study of some of the craters of the region throws some light on the origin of these clays. From the craters fine material, such as scoriaceous ash, is thrown in quantity. With these fine products are also many large bowlders of black, massive igneous rock. Subjected to prolonged decay, this mixture of fine and coarse materials would, it is affirmed, leave a residuum identical in appearance with the bowlder clays. The glacial hypothesis, as an explanation of this formation, is regarded as untenable.

On the slopes of one of the mountains, Irazu, between the altitudes of 7000 and 9500 feet, there is found a fine pulverulent yellow dust, which is "in every way identical in lithological appearance and behavior with the loess deposits . . . . of the Missouri and Ohio." This formation is composed of the minerals common to the lavas of the region, but its mode of accumulation is not discussed.

Comparing the two sections, it is stated that "the Panama section is across an old land now nearly graded to the sea, where vulcanism has been quiescent since the Tertiary time," while "the Costa Rican section presents us a view of an ever-growing land where volcanoes have continued to pile their débris from Cretaceous time to the present."

Under the caption, "The Union of the Continents and the Problems of the Straits," the general relations of the Central American and Isthmian regions are discussed. The meager knowledge at hand indicates that "previous to the vast accumulations of more modern igneous and sedimentary rocks of Tertiary and post-Tertiary age, a foundation of granitic rocks, occurring in east and west arrangement,

existed in the South Isthmian and Central American region, extending in echelon arrangement from the longitude of Trinidad through forty degrees to near that of Acapulco, Mexico, directly across the path of the main continental trends." Palæozoic rocks are known with certainty, in the general area under consideration, in but one region, viz., in the Republic of Guatemala, and the adjacent Mexican border region. Their surface development is certainly very meager south of the United States. Triassic rocks, likewise meager south of the United States, also occur in Guatemala, but Jurassic beds are not known at any point in Central America. Cretaceous strata are much more widely distributed in tropical America; but while they cover most of Mexico, it is doubtful if the two oceans were at any time connected across this country in the Cretaceous period. This conclusion is based on palæontological evidence.

As to the Tertiary beds, the facts now in hand "indicate the existence of a continuous littoral of older Tertiary sediments around the Caribbean side of the tropical American region, and incidentally a preëxisting land which they bordered. . . . . These older Tertiary beds . . . . probably belong to the continuous series of sediments of the Eocene and Oligocene epochs. . . . . The Pliocene formations have not been clearly distinguished . . . . from the Pleistocene. There is an intermittent fringe of alleged Pliocene deposits around the Caribbean coast, unconformably deposited against the older continental mass. . . . . We may infer from the relatively slight area of the marginal development of rocks of this period, and their absence in the elevated or folded regions away from or much above the coast line, that it was just prior to the Pliocene period or during its earlier days that the Caribbean coast line, as a result of the tremendous orogenic processes by which the earlier Tertiary rocks were deformed, practically assumed the slope as we now know it."

In elaboration of this point, it is further stated that the early Tertiary strata have "since their deposition been elevated above the sea to great heights by folding on the Caribbean side of the old Isthmian protaxis until they stand 3000 feet in Guatemala, 5000 in Talamanca, 300 near Colon, and 500 at Cartagena. . . . . In Hayti, Cuba, and Jamaica, these plicated, Cretaceous, and early Tertiary rocks are found at altitudes exceeding 10,300, 8000, and 7250 feet, respectively, above the ocean. The east and west strike both of the Tertiaries and of the basic igneous rocks along the northernmost coast of South America

and in the Great Antilles is directly in harmony with the east and west trend of the same phenomena upon the mainland, and we cannot escape the conclusion that they are the product of the same great orogenic revolution, the age of which was mid-Tertiary, for rocks of early and late Eocene (and Oligocene) age everywhere, as exposed along the Caribbean coast, and in the Great Antilles, are folded by these mountain-making processes, while the Pliocene and Pleistocene are more horizontally laid down against the seaward margin of the mountain masses."

It is worth noting that the great orogenic movements of this region, dating from the later part of the Miocene, are in harmony with the great disturbances which took place in several continents at about the same time. They furnish a significant commentary on the infelicity of the current grouping of the Miocene and Pliocene under the common name Neocene. Nearly everywhere outside the regions of glaciation, the Pliocene and Pleistocene are more closely associated than the Miocene and Pliocene. The above use of the term Neocene makes this *period name* cover an interval of time in the midst of which occurred one of the most profound physical revolutions to which the earth's crust has been subject. For such use of the term there is but one analogy in the nomenclature of post-Algonkian time, namely, that of the use of the term Silurian, to cover all beds between the Cambrian and Devonian, although in the midst of this division occurs the greatest break, both stratigraphic and palæontologic, in the whole Palæozoic. The other physical revolutions comparable to that which took place at the close of the Miocene mark not simply the close of periods, but of eras.

In post-Miocene time, or perhaps accompanying the orogenic movements referred to, there was epeirogenic uplift and erosion, followed by moderate subsidence, and still later by uplift of slight extent, converting the shallow margin of the sea into low-lying coast lands.

The igneous rocks of the region appear to have a wide range in age. The age of the granitic mountains of east-west trend is not known, but they seem to be mainly pre-Tertiary, and probably pre-Cretaceous. Some of them may be much older. The later igneous rocks of the region seem to date in part from the later part of the Cretaceous period. Here belong the rhyolitic tuffs of the Panama formation which is believed to be pre-Tertiary. In the early Tertiary also there was great volcanic activity, but whether the vulcanism of the

close of the Cretaceous, with its accompanying disfiguration of topography, "was continuous to the present, or alternated with long periods of quiescence, cannot be answered." Thus volcanic activity accompanied the orogenic movements of Miocene time, giving "the most cataclysmic revolution of all geologic time and place."

Summarizing the evidence touching the union of the northern and southern continents, it is said that nothing is known of their relations in the Palæozoic; that land may have been continuous between them in the early Mesozoic; that it was probably so in the Cretaceous; and that in the Tertiary period only, in later geologic time, does the connection of the oceans across tropical America seem to have been possible. For their connection, even in this period, the evidence is much less conclusive than is commonly believed. For such connection "no stratigraphic proof has been discovered," and the physical character of the Tertiary sediments seems to be distinctly against any broad union. The only evidence pointing to their connections is palæontological, and even this is meager. In a single terrane of the Eocene, five species of mollusks on the Caribbean side of the Isthmus occur also in the Tejon Eocene of California. These species are held to indicate that in the Tejon epoch there was at least a shallow communication between the oceans, and that "to this epoch alone can the date of an interoceanic connection be assigned by direct palæontological evidence. . . . . All the authentic biologic and geologic evidences are entirely opposed to the possibility of a communication between the two oceans across the Isthmus or tropical American region in Pliocene or Pleistocene time." The statement of Upham, Spencer, and others, that marine Pleistocene fossils have been found at great heights on the Isthmus, is said to be erroneous.

R. D. S.